METHOD AND APPARATUS FOR CONDITIONING A COOLING PROCESS REGION IN ORDER TO REDUCE CORROSION

Description

[0001] The invention relates to a method and an apparatus for conditioning at least a subregion of a cooling process region.

[0002] A production process known as the float glass process is known in practice for the production of flat glass. In this process, first of all glass melt is produced continuously by melting a batch of mineral glass raw materials, which in addition to SiO_2 typically also comprise Al_2O_3, CaO, MgO, Na_2O, K_2O and in some cases also Fe_2O_3 and TiO_2 or SO_3, in a heated glass tank or a melting furnace. The glass melt is poured onto a tin bath comprising liquid tin and spreads out uniformly on the tin bath under the force of gravity and surface forces, in the form of a glass ribbon or glass film, which then floats on the liquid metal. This zone is therefore also known as the float zone. The temperature on the tin bath is initially typically approximately 1000°C. Then, the glass ribbon is cooled to approximately 600°C to 700°C while it is still on the tin bath and then pulled off the tin bath by means of rollers arranged at the edge.

[0003] The glass ribbon which has been pulled off is then transported via a conveyor belt through a cooling installation, which comprises a cooling furnace and a cooling section and is referred to as the annealing lehr. Controlled, relatively slow cooling of the glass is performed in the cooling installation to avoid thermally induced internal stresses in the glass, a process also known as annealing. This is because normally, the glass ribbon would cool down more quickly on the flat sides than in the interior, and the stresses which these high temperature gradients produce in the glass would lead to cracks and fractures in the glass ribbon in particular during the subsequent cutting into

individual panes. During the annealing, a temperature profile which is controlled by means of temperature sensors and controllers is accurately maintained so as to keep in particular the temperature gradients in the glass ribbon at a low level and to allow stress relief processes to take place in the glass. For example, the glass is typically cooled to what is known as an annealing temperature and then held at this temperature for a defined period of time, the period of time being dependent on the type of glass, the glass thickness, the coefficient of thermal expansion and the desired residual stress. At this annealing temperature, relaxation processes take place in the glass in order to reduce the internal stresses. Then, the glass is cooled again with a predetermined temperature gradient. After they have passed through the cooling section, individual flat glass units are separated from the moving glass ribbon and then stored in a store prior to further processing or transport. The entire float glass process described in practice takes place continuously, i.e. the glass ribbon is continuously pulled off the tin bath and corresponding amounts of glass batch and glass melt produced therefrom are added.

[0004] During the glass melting process, at the high melting temperatures in the glass tank, the glasses are formed from the starting substances as a result of the batch reaction. This process is also referred to as melting until batch free time. After the melting until batch free time has ended, the result is a very inhomogeneous melt, in which the SiO_2 concentrations which occur as the main constituent of the glass range from saturation concentration to at least the desired concentration and moreover the melt contains large numbers of bubbles which contain reaction gases and included cavity gases, in particular air or water vapor. Therefore, in what is known as the melting until seed free, the bubbles which are formed are expelled in a refining process, in particular using suitable refining agents to realize the gas supersaturation required

during the refining, followed by standing off of the melt with homogenisation. At the end of the standing off process, the melt is poured onto the tin bath and forms the glass ribbon.

[0005] EP 1 285 887 A2 has disclosed a float glass process in which, in a melting zone of a glass melting furnace, heat is generated by the combustion of fuel and oxygen enriched oxidation gas (or: gaseous oxidizing agent) containing at least 80% by volume oxygen in burners, in order for molten glass to be produced from glass raw materials. Typical fuels mentioned are methane, propane, oil and hydrogen. The molten glass is applied to the surface of a molten metal, typically molten tin, in a tank, where it spreads out and in the process forms a pane or plate of glass (flat glass). Then, the flat glass is transferred into an unfired refining zone or zone for melting until seed free, where it is cooled without combustion of fuel and oxidizing agent. The use of oxygen enriched fuel gas has the advantage over combustion using air typically containing 20 to 21% by volume oxygen that a greater efficiency, improved refining reactions, higher temperatures, a lower gas volume and a lower formation of particles and nitrogen oxides are achieved. However, the concentration of water vapor in the atmosphere of a glass melting furnace fired with oxygen enriched oxidation gas rises to 50 to 65% by volume, compared to 15 to 20% by volume in a furnace fired with an air/fuel mixture. EP 1 285 887 A2 then describes that this higher water vapor pressure in the atmosphere has the effect of small gas bubbles filled with water vapor which are formed during the refining process not being dissolved and remaining in the end product, with the result that higher scrap rates are observed.

[0006] As a possible solution to this problem, EP 1 285 887 A2 considers reducing the partial pressure of the water at the glass surface in the regions in which the small gas

bubbles need to be desorbed, by blowing air into the furnace in the vicinity of its exit, in order to reduce the concentration of combustion products and therefore in particular also water at the glass surface. However, some drawbacks of this potential solution are cited, in particular the reduction in energy efficiency, the rise in nitrogen oxide emissions and also the rise in gas volume which leaves the furnace.

[0007] Therefore, EP 1 285 887 A2 proposes, as a better solution, that some of the oxidation gas, prior to combustion, be passed through the refining zone or in the region close to the exit of the furnace, specifically at a sufficiently low velocity below 16.6 m/s to avoid mixing of the oxidation gas with gases above. The stream of oxidation gas which is passed through lowers the water vapor content in the atmosphere at the surface of the molten glass in the refining zone to less than 25% by volume. EP 1 285 887 A2 also states that any other dry gas which does not chemically react with the glass, in particular air, fuel gas or carbon dioxide, could be used to remove water vapor instead of the oxidation gas.

[0008] The further published document EP 1 206 422 B1 has disclosed a cooling furnace or tunnel furnace for the thermal annealing or stress relief cooling of flat glass, in which a glass ribbon is passed through three cooling zones in succession, namely a precooling zone (A), a cooling zone (B) and an post cooling zone (C). A group of cooling air heat exchangers, which cool the glass ribbon passing through by radiant heat exchange, is arranged in each of these cooling zones. By measuring the temperature and controlling the cooling air flowing through the heat exchangers, the temperature in the individual cooling zones is controlled, resulting in a shallow negative spatial temperature gradient in the transport direction, from a starting temperature of approximately 600°C down to a temperature of approximately 360°C, the magnitude of

the temperature gradient being lower in the pre cooling zone than in the cooling zone and in the post cooling zone. Downstream of the post cooling zone is provided a cooling section with further cooling zones (D and F), in which the glass is cooled further down to an ambient temperature by direct cooling through air convection. Therefore, whereas in the cooling furnace or tunnel furnace ambient air serves only as indirect cooling medium via the heat exchangers and the cooling takes place by exchange of thermal radiation, in the subsequent cooling section, which in EP 1 206 422 B1 corresponds to the last two zones (D, F), ambient air is provided as direct cooling medium which is passed directly onto the glass ribbon. In the intermediate zones (X and Y) between the main zones (A, B, C) there are regions in which the glass can be heated up again in an undesirable way, i.e. a positive temperature gradient may occur. To avoid this problem, it is proposed to use a heat exchanger unit which extends over the entire cooling furnace, including the intermediate zones. In the heat exchanger unit there are outlets for releasing warm air to control the temperature, as well as valves for controlling the quantity of ambient air supplied.

[0009] The internet page www.energie.industrie.de dated 18.03.2003 has disclosed a method for energy recovering or waste heat utilization in fossil heated glass melting tanks in a Schott Glas plant in Mainz. In a first step, heat which has not been used and is contained in the combustion gases is used as a hot off gas stream from the glass tanks to preheat the combustion air. In a second step, the thermal energy which is still present is used to generate hot water, thereby covering the entire heat demand for room heating and hot water supplies for the plant. Since the heat demand is lower in summer on account of the weather, yet at the same time the demand for air conditioning refrigeration rises, it is stated that it is recommended to utilize the heat to generate air

conditioning refrigeration by means of absorption refrigeration machines. Three lithium bromide absorption refrigeration machines are used for this purpose; one machine starts to operate above an outside temperature of 0°C, and all three machines start to operate above 26°C.

[0010] The same internet page describes a further method for utilizing the waste heat generated in the glass melting process by Hermann Heye, Germersheim. In this case too, some of the waste heat is utilized to preheat the combustion air by means of a two stage recuperator. The ambient air is preheated from ambient temperature to approx. 800°C and then fed for combustion. The residual heat which remains is fed to a boiler installation at a temperature of approx. 730°C, where steam is generated and is then converted into electrical energy in a condensation turbine. This generates electricity for use in the plant. The remaining waste gas, which is still at a temperature of approx. 145°C, passes via a filter installation into the stack.

[0011] One problem which is known in practice is the varying quality of the surfaces of the flat glass produced using the float glass process; in summer, the quality deteriorates and scrap rates increase compared to in winter. Quality problems cause in particular the formation of a gel layer with a silica like composition, which is disruptive for the further processing, in particular finishing or coating of the glass, and also the leaching and corrosion of the glass surface. These surface problems occur predominantly on the atmosphere side of the glass pane, i.e. the side which in the tin bath did not face the tin. The various phenomena mentioned above are referred to globally in the present application by the unifying term corrosion, which is intended to encompass all physical or chemical processes which alter the structure or composition of the glass surface through reaction with the adjoining atmosphere.

[0012] In addition to the reactions with the atmosphere gases oxygen, nitrogen and carbon dioxide, in particular the reaction of the glass with water from the atmosphere is of relevance. According to current knowledge, the water vapor which reacts with the glass at the glass surface leads to an increase in the alkali metal ion concentration at the surface of the glass and to the formation of corresponding alkali metal hydroxides or lyes, which attack (leach) the glass. Furthermore, what are known as silanol groups are formed, which alter the optical and mechanical properties of the glass, in particular cause discoloration and make the glass softer at the surface than in the interior of the glass pane, for which reason it is possible once again to speak of a gel layer. The precise chemical and physical sequences of glass corrosion have not yet been fully clarified.

[0013] Glass corrosion has a number of serious drawbacks. For example, during handling of the glass panes in the store, suckers can produce sucker imprints on the gel layer of the glass pane surfaces. Furthermore, during storage of the glass panes, atmospheric humidity and condensation of water on the surfaces of the glass produce a corrosion and gel layer of such an extent that it is even possible for panes which bear against one another in pane stacks to, as it were, stick to one another. In the stores, it is therefore ensured that the glass panes are spaced apart in the stacks with the aid of spacers, that the air between the glass plates is continuously circulated and the temperature is kept as constant as possible in the storage rooms, and that the storage buildings are protected against the penetration of a humid atmosphere. A further glass corrosion problem is that defects or a lack of quality can occur when coating or finishing on the gel layer or corroded layer.

[0014] Corrosion to the glass, once it has occurred, is fundamentally irreversible and is cumulative at the glass surface; its occurrence can only be eliminated by removing the

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corroded surface layer. The glass panes are generally coated, which can stop further glass corrosion. In practice, therefore, the storage time and transport time until coating of the glass are kept as short as possible or else the coating is carried out immediately after the glass production process straight away in a single process by means of a downstream coating installation.

[0015] The problem of corrosion of the glass surface is not discussed in EP 1 285 887 A2 or EP 1 206 422 B1 and is also not solved in any way.

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[0016] The invention is now based on the object of providing a method and an apparatus which can be used to reduce or delay the corrosion of a glass surface caused by or in the presence of water vapor in the atmosphere adjoining the surface.

[0017] According to the invention, this object is achieved by the method having the features of claim 1 and the apparatus having the features of claim 35.

[0018] The method as claimed in claim 1 is suitable and intended for conditioning at least a subregion of a cooling process region, in which during a cooling process at least one shaped body, which has been shaped in a shaping process, preferably from a melt, is cooled in accordance with a predetermined or predeterminable (spatial and/or temporal) temperature profile, with thermally induced mechanical stresses in the shaped body being kept at a low level, and comprises the following method steps:

      a)   passing at least one conditioning gas over at least one surface, which can be corroded in the presence of water, of the shaped body at least during part of the cooling process,

      b)   setting (or controlling) the absolute water content in the conditioning gas (as a conditioning variable) into a range up to at most a predetermined or predeterminable limit value, specifically at least when the conditioning gas enters the cooling process region and/or when the conditioning gas strikes the surface of the shaped body.

[0019] The apparatus as claimed in claim 35 is suitable and intended for conditioning at least a subregion of a cooling process region for cooling at least one shaped body which has been shaped in a shaping process, preferably from a melt, in accordance with a predetermined or predeterminable temperature profile, with thermally induced

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mechanical stresses being kept at a low level in the shaped body, and preferably also for carrying out a method according to the invention, and the apparatus comprises at least one drying device for drying at least one conditioning gas to an absolute moisture content of at most a predetermined or predeterminable limit value, and at least one conditioning gas device for passing dried conditioning gas from the at least one drying device to the cooling process region.

[0020] The invention is based on the surprising and new discovery that glass corrosion does not occur for the first time in the store or during transport, but rather while the glass is still in the cooling furnace the cooling section and even equates to a considerable amount at this stage, since during the cooling of the glass, considerable quantities of moisture are often introduced into the cooling process as a result of the supply of ambient air, leading to the problems with corrosion. Based on this new discovery, the invention is also based on the consideration of supplying conditioned gas, in particular conditioned air, with an absolute water content which is below a predetermined or predeterminable limit value during the stress relief cooling of the glass produced from the melt (i.e. during the annealing), thereby keeping the water vapor content at the glass surface which is at risk of corrosion at a low level. It is in this way possible to considerably reduce the corrosion to the glass. The limit value for the absolute water content in the conditioning gas is preferably matched to a desired maximum degree of corrosion or a maximum permissible increase in the degree of corrosion (or increase in the corrosion) during the cooling process.

[0021] This solves a demand which has long existed in the specialist field, since it is no longer the case that different qualities of glass occur in summer and in winter, but rather a glass surface quality which remains virtually constant, and is even improved, over the

entire year with respect to corrosion by water can be achieved. Defects linked to glass corrosion, such as sucker imprints or coating defects, are avoided or at least reduced, and the ability to store the glass is improved. This is possible with the conditioning according to the invention without a coating being applied to the glass surface to protect against corrosion. The invention can be applied to all glass shaped bodies, in particular flat glass and hollow glass bodies.

[0022] The invention is also based on the consideration that the process conditioning of the surface with dry conditioning gas is suitable not only for the production of glass but also for the production of all materials or process products which are to be subjected to annealing and change structure or composition at their surface as a result of reaction with water in the adjoining atmosphere, for example including steels. The degree of corrosion to the process product which can be established at the end of the cooling process or the production process according to the invention should therefore be kept below a predetermined value by the conditioning of the atmosphere of the process at least during part of the process.

[0023] Advantageous configurations, refinements and applications of the method and the apparatus will emerge from the claims which are respectively dependent on claim 1 and claim 35.

[0024] In general, the cooling process region comprises a cooling furnace and/or a cooling section and the conditioning gas is then fed to the shaped body at least in a subregion of the cooling furnace and/or cooling section. The region within the cooling process region through which the conditioning gas is passed may be selected from a region near to the surface of the shaped body, on the one hand, through to the entire cooling process region, on the other hand.

[0025] In an advantageous embodiment, the conditioning gas used is air or a gas with a composition which at least approximately corresponds to the composition of air, preferably ambient air from an environment located outside the cooling process region and/or from an outside environment outside a building surrounding the cooling process region, the ambient air in this case preferably being sucked in and then filtered. However, it is also possible to use a conditioning gas with a different composition, in particular a higher proportion of inert gas, in particular carbon dioxide, nitrogen or a noble gas, for example argon, and/or to set or alter the composition of the conditioning gas as a further conditioning variable.

[0026] Furthermore, it is preferable for the purity of the conditioning gas to be controlled or set, in particular by filtering, and/or for the temperature of the conditioning gas to be controlled or set, in particular in a temperature range between 5°C and a process temperature in the process region, as further conditioning variables.

[0027] The mean flow velocity of the or each conditioning gas flow is preferably set to between approximately 5 m/s and approximately 20 m/s. In general, the conditioning gas flow is substantially steady (time independent).

[0028] In one variant, the conditioning gas is used only once in the process and is discharged to a surrounding environment after it has been used in the processes. In another variant, the conditioning gas is passed through a circuit and is dried each time it passes through the circuit after use in the process.

[0029] In a particularly advantageous embodiment, the method according to the invention is deployed or used in a method for producing shaped bodies, in which in a melting process at least one raw material is converted into the melt, at least one shaped body is shaped from the melt in a shaping process, and this/these shaped body/bodies

is/are cooled in at least one cooling process region, with the method according to the invention being carried out to condition the cooling process region at least in a subregion.

[0030] The shaped bodies are preferably produced from glass. During the shaping process, it is then preferable for glass melt to be applied to a liquid carrier medium, in particular liquid metal, preferably tin, and for a flat shaped body to be formed in the form of a layer or a ribbon of glass on the surface of the liquid carrier medium. The flat shaped body is then usually transported off the carrier medium and fed to the cooling process or cooling system.

[0031] In an industrial process, it is preferable to produce a continuous shaped body or for the shaped body to be produced continuously from the melt and for the shaped body to be cut or divided into individual shaped bodies following the cooling process.

[0032] To allow the low degree of corrosion to the shaped bodies, in particular the shaped glass bodies, achieved as a result of the conditioning of the cooling process region to be preserved or maintained as far as possible or at least to limit the rise in this degree of corrosion, in a particularly preferred embodiment the shaped bodies, even after cooling, continue to be conditioned with dry conditioning gas, in particular dry process air, and are thereby substantially protected from the action of water. A subsequent conditioning of this nature can be effected by passing the dry conditioning gas onto or over the surface(s) of the shaped bodies in a store and/or during transport, for example in a truck, a container or the like, and/or before or during further processing or treatment of the shaped bodies, in particular coating, finishing and/or processing to form laminated bodies.

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[0033] However, conditioning with dry conditioning gas is also advantageous prior to the cooling of the shaped body, in particular during the shaping process, during the melting process and/or even for the raw materials for melting.

[0034] For example, dry conditioning gas can be used for a combustion process for burning, in particular oxidizing, fuel to heat the raw materials during the melting process, and can in particular be fed to burners for burning the fuel. Even taking account of water which is additionally formed during the combustion process, this reduces the influence of water in the combustion atmosphere on the surface of the melt or the shaped body which gradually solidifies from the melt, thereby improving the materials properties. It is in this way possible in particular to have a positive influence on the surface tension so as to reduce the formation of bubbles. At least the rear burners downstream of the foam limit should be operated with dry process air. Furthermore, dry conditioning gas can be passed over a surface of the melt and/or over at least one surface of the shaped body (bodies) during at least part of the shaping process. In particular, in the process disclosed in EP 1 285 887 A2, which was cited in the introduction, the conditioning gas can be used to flow over the glass ribbon in the refining zone of the melting furnace. Moreover, it is also possible for dry conditioning gas to be passed over or through the raw material(s) or the batch prior to the melting process.

[0035] At least one conditioning device preferably comprises feed means for feeding conditioning gas and at least one exit opening, which is arranged or opens out in the cooling process region, as an exit for the conditioning gas, in which case the feed means are or can be flow connected to the at least one exit opening.

[0036] Since the literature uses contradictory terms for the physical variables pertaining to moist air or in general terms moist gas, a brief description will be given at this point of the definitions and relationships within the meaning of the present application.

[0037] The water content of the conditioning gas, in the as yet unsaturated state, substantially comprises water vapor (or moisture, water content in the gaseous state), and in the supersaturated state it additionally also includes water droplets which are entrained or suspended in the conditioning gas (i.e. water in liquid form). At saturation or the associated saturation pressure, given a constant temperature an equilibrium prevails between a liquid and its vapor in any predetermined volume.

[0038] The absolute water vapor content or the moisture loading X corresponds to the quotient formed from the mass of water vapor (vapor mass) contained in the conditioning gas, measured for example in grams (g), and the mass of the dry remaining conditioning gas (dry gas mass), usually given in kg, with both masses being determined in the same gas volume, for example one cubic meter (1 m3), at the same temperature and the same pressure. The absolute vapor content or the moisture loading X is therefore a dimensionless variable.

[0039] The relative water vapor content or the relative moisture content φ is based on the saturation state and is defined as the quotient formed from the partial density or concentration of the water vapor at the predetermined temperature, for example measured in g/m3, and the saturation partial pressure of the water vapor which is or would be set on reaching the saturation partial pressure of water, i.e. on the conditioning gas becoming saturated with water, at the same temperature, likewise measured in g/m3. The relative moisture content also corresponds to the quotient formed from the current vapor partial pressure and the saturation vapor partial pressure. The relative

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moisture content is dimensionless and is usually expressed in percent (%); in the subsaturated state, the relative moisture content is under 100%, and in the saturated state it is 100%. The relative moisture content of a gas, for example air, with a predetermined moisture loading or absolute moisture content, decreases as the temperature rises given the same pressure. Given the same relative moisture content and the same pressure, the gas in absolute terms contains more moisture at the higher temperature than at the lower temperature. The warmer gas can therefore take up more moisture than the cooler gas.

[0040] The absolute moisture loading of the conditioning gas, in particular the conditioning air, is in a particularly advantageous embodiment kept at less than or at most equal to 0.006, i.e. 6 g of water per 1 kg or 1000 g of dry gas ($X \leq 0.006$). This applies to the conditioning of the cooling process region, but preferably also for the abovementioned conditioning of additional process regions.

[0041] This maximum absolute moisture loading $X = 0.006$ as the absolute limit value corresponds to a limit value for the relative water content or the relative moisture content of 30% at 25°C or 20% at 32°C or 10% at 45°C. With regard to the relative or absolute water content which is set, it is generally necessary to refer to the entry of the conditioning gas to the process region, since the conditioning gas generally takes up moisture again in the process region. With these degrees of dryness or low water contents of the conditioning gas, the water content of the atmosphere at the surface of the shaped bodies is reduced to such an extent that corrosion to a glass surface in the conditioned process region is almost completely avoided.

[0042] In a particularly advantageous embodiment for drying the conditioning gas, i.e. for extracting moisture from the conditioning gas, refrigeration is generated by means

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of a refrigeration circuit or a refrigeration machine, and the refrigeration which is generated is used to condense moisture out of the conditioning gas in order to dry the conditioning gas (refrigeration drying, condensation drying). Refrigeration machines which can be used in particular to dry the conditioning gas include compression refrigeration machines and/or absorption refrigeration machines.

[0043] Refrigeration machines dissipate heat from a region that is to be cooled to a release region. For this purpose, in most refrigeration machines, a refrigerant is evaporated in an evaporator, which exchanges heat with the region that is to be cooled, and in this way the enthalpy of vaporization or heat which is required for the evaporation of the refrigerant is withdrawn from the region that is to be cooled. Then, the refrigerant is released again in a condenser or liquefier, which exchanges heat with the release region, the heat corresponding to the enthalpy of vaporization is liberated again and released to the release region. The liquefied refrigerant is then fed back to the evaporator and the circuit begins again from the beginning. Since the temperature is generally higher in the release region than in the region to be cooled, operating energy is required for the refrigeration machine to overcome this negative temperature gradient.

[0044] In the case of a compression refrigeration machine, a compressor, which sucks in the vapor of the refrigerant from the evaporator, compresses it and then feeds it to the condenser, is generally operated with electrical energy. The increased pressure which is brought about in the refrigerant vapor in this way then allows liquefaction of this vapor, with both the thermal energy corresponding to the enthalpy of vaporization and the compression energy being released to the release region in the condenser. The condensed refrigerant is fed back to the evaporator via a throttling section in order to build up pressure in the condenser during compression.

[0045] In the case of an absorption refrigeration machine there is an absorber circuit, in which a liquid or gas as refrigerant is absorbed in a (further) liquid as solvent in an absorber and is then separated or desorbed again from this liquid in a boiler or expulsion means by supplying heat as thermal operating energy, for example a system comprising lithium bromide as solvent and water as refrigerant or a system comprising water as solvent and ammonia as refrigerant. The refrigerant has a lower evaporation point or boiling point than the solvent. The refrigerant vapor generated in the evaporator is fed to the absorber and absorbed in the solvent. The solution of solvent and refrigerant is pumped to the boiler via a solution pump. When it reaches the boiler, the refrigerant is expelled from the solution by the supply of heat, and the refrigerant vapour which has been expelled is fed to the condenser, where it is liquefied, releasing heat to the environment surrounding the condenser. The liquid refrigerant then returns to the evaporator.

[0046] Then, the conditioning gas which is to be dried is generally introduced into the region of the refrigeration machine which is to be cooled or has been cooled, and this gas exchanges heat with the evaporator, for example in a heat exchanger which is connected into a feed line for the conditioning gas. The water which has condensed out and precipitates on walls is collected in particular in a condensate collector and pumped out at regular intervals or continuously. The condensed water which is still entrained in the conditioning gas in the form of droplets is preferably separated off in a droplet separator known per se, and the condensate water formed is likewise removed.

[0047] Then, the dried conditioning gas is preferably heated back to a desired conditioning temperature, for example in a further heat exchanger or a heating device which is connected into the feed line for the conditioning gas.

[0048] In addition or as an alternative, it is also possible to dry the conditioning gas by water vapor being adsorbed or absorbed or taken up at an adsorbing, absorbing or hygroscopic material, e.g. silica, followed by regeneration or expulsion in particular by means of a regeneration device, which preferably utilizes the process waste heat as heating energy.

[0049] It is also possible to combine various forms of drying, for example drying with absorption refrigeration machine(s) as base load and additional drying with compression refrigeration machine(s) and/or hygroscopic material for further or subsequent drying.

[0050] A crucial variable for the technical consideration of what energies are required to alter the moisture content in the conditioning gas is the enthalpy h of the moist gas, which is composed of the enthalpy hg of the dry gas and the enthalpy hd of the vapor. The enthalpy hg of the dry gas approximately corresponds to the product of the temperature T and the specific heat cg of the dry gas. The enthalpy hd of the vapor approximately corresponds to the sum of the product of temperature T and specific heat cd of the vapor, on the one hand, and additionally the enthalpy of vaporization, on the other hand.

[0051] In practice, use is very often made of what is known as the Mollier diagram, which plots the enthalpy h of the moist gas, usually moist air, against its moisture loading X, in which diagram it is also possible for the moisture loading X to be read off on the abscissa and the temperature T to be read off on the ordinate. Isotherms are indicated starting from the corresponding temperature values on the ordinate as straight lines with an inclination which increases with the temperature. Furthermore, the Mollier diagram includes isenthalpic lines, which are parallel straight lines running downward toward the right having the inclination of the negative enthalpy of vaporization, and also

convexly curved parameter curves indicating identical relative moisture content φ, the saturation curve for φ = 100% being located furthest downward, and the curves for φ < 100%, i.e. the subsaturation range, being located above this saturation curve, and the supersaturation region or fog region being located below this saturation curve.

[0052] The Mollier diagram in particular makes it clear what temperature difference and what energy or power are required in order, for example in a refrigeration circuit, to achieve a desired reduction in the moisture loading X of the conditioning gas and thereby to achieve a corresponding relative moisture content in the conditioning gas.

[0053] In the preferred embodiment in which ambient air is used as conditioning gas, with this ambient air being sucked in from an environment and having foreign substances removed from it in a filter, the various applications, in particular the following numerical example, can be taken from the Mollier diagram:

[0054] If the ambient air initially contains a relative moisture content φ = 60% at a temperature of 30°C, which is a possible atmospheric condition in summer, the (absolute) moisture loading X of the moist air is approximately 0.017 or 17 g of water per 1 kg of dry air.

[0055] If it is then desired to reduce this absolute moisture content to 0.006, i.e. 6 g of water per 1 kg of air, the air is cooled to approx. 6.5°C and, after the water which has condensed out has been removed, is heated back to the original temperature of 30°C without admitting further moisture. The absolute moisture content X is then (still) 0.006 and the relative moisture content φ drops to about 24%. The enthalpy required for this process amounts to approximately 27 kJ/kg, and consequently a corresponding heat quantity of at least 27 kJ per kg of moist air has to be made available to the refrigeration machine.

[0056] If, in a further example, the starting point used is an ambient air temperature of 35°C and a relative ambient air moisture content of $\varphi = 65\%$, corresponding to a moisture loading of approximately $X = 0.024$, the same drying to an absolute moisture content of $X = 0.006$ would require an enthalpy difference of 73 kJ/kg.

[0057] The volumetric flow of the conditioning gas stream, in particular of the ambient air, may typically be selected to be between 10,000 and 500,000 m3/h.

[0058] The refrigeration capacity required to dehumidify a predetermined quantity of air can be calculated according to the relationship whereby the refrigeration capacity is the product of the air density, the enthalpy (difference) and the volumetric flow. In the abovementioned example of dehumidifying air from a moisture loading of $X = 0.024$ to $X = 0.006$, by way of example a refrigeration capacity of 0.24 MW at a volumetric flow of 10,000 m3/h, a refrigeration capacity of 2.43 MW at a volumetric flow of 100,000 m3/h, a refrigeration capacity of 6.08 MW at a volumetric flow of 250,000 m3/h and a refrigeration capacity of 12.16 MW at a volumetric flow of 500,000 m3/h would be required.

[0059] To allow these very high refrigeration capacities to be made available in an economically viable way in particular with relatively large quantities of air, in a particularly advantageous embodiment heat recovery is implemented from process waste heat from the melting process and/or the shaping process and/or the cooling process. It is preferable for the process waste heat to be used as operating energy for the refrigeration circuit or the refrigeration machine(s) for the condensation drying of the conditioning gas, for example directly as thermal energy in the absorption refrigeration machines or the regeneration heating devices or by conversion by generator into electrical energy for the compression refrigeration machines.

[0060] The conditioning of a or the process region and/or the passing or flowing of conditioning gas over the shaped body (bodies) can in all embodiments take place continuously, i.e. substantially without interruption, or discontinuously, i.e. with interruptions or in specific conditioning intervals or conditioning phases.

[0061] In particular, it is possible for one or more shaped bodies to be sealed or closed off in a gastight manner in a vessel or container or a sheath, for example a, preferably shrink fitted, plastic film, and for the gas atmosphere in the container or the sheath to be dried in advance or set to a low absolute or relative moisture content, in particular according to the abovementioned limit values during conditioning. This is advantageous in particular for transporting the shaped bodies even over longer distances. If appropriate, the atmosphere in the container or the sheath can also be replaced or reconditioned from time to time in order to remove any moisture which has penetrated in.

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[0062] The invention is explained in more detail below on the basis of an exemplary embodiment of a completely conditioned flat glass production process or installation based on the float glass process. In this context, reference is made to the only figure, which shows an entire process/installation in the form of a diagrammatic outline sketch.

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[0063] A batch feed device 2 supplies a batch of mineral glass raw materials to a region 30 for melting until batch free in a glass melting device (or glass melting tank) 3. In the region for melting until batch free 30, the batch is melted down to form a melt which is free of batch. In a subsequent region for melting until seed free 31 of the glass melting device 3, the glass melt (seed free melt) is refined. The hot waste gases A from the glass melting device 3, in particular the region for melting until seed free 31, are discharged outwards to atmosphere via a waste gas discharge device 32, which in particular comprises pipelines and/or a stack.

[0064] The refined glass melt is then fed from the region for melting until seed free 31 of the melting device 3 to a float bath, in particular a tin bath 4. The glass melt is poured onto the liquid metal, in particular tin, and spreads out in the form of a ribbon or layer on the bath. Whereas the temperature during the melting process in the glass melting device 3 is still, for example, 1100° to 1400°C, the temperatures in the float bath 4 are 1000°C at the entry and approx. 600°C to 700°C at the exit.

[0065] The viscose glass ribbon which is formed is pulled off the float bath 4 and guided through a cooling device 7. In the process, the glass ribbon passes firstly through a cooling furnace 5 and then through a cooling section 6 of the cooling device 7. Indirect cooling by dissipation of thermal radiation to heat exchangers with a secondary cooling circuit is carried out in the cooling furnace 5. In the cooling section 6, cooling air which is passed directly onto the glass ribbon is used for cooling purposes.

[0066] At the end of the cooling section 6 there is a separation device (not illustrated), which can be used to cut individual raw glass panes, typically with dimensions of 5 m by 5 m, out of the glass ribbon. The raw glass panes are then stored in a glass store 8. From the glass store 8, the raw glass panes or panes which have already been cut to

their final dimensions, are fed to a coating installation 9, in particular a magnetron coating installation, glass finishing or other glass processing 10 or also to a laminated safety glass (LSG) and/or insulation glass installation 11.

[0067] The waste gases A which emerge from the glass melting device 3 into the waste gas discharge device 32 still contain a considerable heat quantity Q or waste heat. This waste heat Q is used in a waste heat recovery system for process air conditioning at various locations within the process.

[0068] A first waste heat quantity Q1 is branched off from the waste heat Q at a first heat branch 33 of the waste gas discharge device 32 and is used to preheat the combustion air for the burners of the glass melting device 3, which are assigned in particular to the region for melting until batch free 30. For this purpose, the heat quantity Q1 is fed via the heat branch 33, in particular via heat exchangers or recuperators, to a combustion air preheating device 14.

[0069] The remaining heat quantity of the heat quantity Q1 is fed to a batch preheating device 13, which preheats the batch in the batch feed device 2 and for this purpose likewise comprises heat exchangers for recuperators. Of course, it is also possible to provide a separate heat branch for the batch preheating device 13.

[0070] At a further heat branch 34 at the waste gas discharge device 32, a second heat quantity Q2 is removed from the remaining heat quantity Q - Q1 transported by the waste gas A and is fed to a refrigeration generation device 15, which generates refrigeration from the waste heat Q2 by means of at least one absorption refrigeration machine. This refrigeration is fed via a first refrigeration line 40 to a first condensation drying device 16 and via a second refrigeration line 41 to a second condensation drying device 17.

[0071] In the condensation drying devices 16 and 17, ambient air U is dried by means of the refrigeration supplied by the refrigeration generation device 15 as a result of the moisture contained in it being condensed out, to a predetermined absolute moisture content or moisture loading.

[0072] The air UT which has been dried by the first condensation drying device 16 is then fed via an air feed 50 to the batch feed device 2 for conditioning, in particular drying or setting a predetermined degree of drying of the batch.

[0073] The second condensation drying device 17 feeds dried ambient air UT via an air feed 51 to the region for melting until batch free 30 in the glass melting device 3, via a further air feed 52 to the region for melting until seed free 31 and via a third air feed 53 to the float bath 4. For this purpose, air outlets are generally arranged above and/or laterally with respect to the glass melt or glass ribbon, through which air outlets conditioned ambient air UT is introduced and passed onto the glass melt or glass ribbon in the float bath 4 for the purpose of conditioning the glass melt or glass, in particular keeping the moisture content below a defined value.

[0074] A third heat quantity Q3 is branched off from the residual heat Q - Q1 - Q2 which remains in the waste gas A via a third heat branch 35 at the waste gas discharge device 32 and is fed to a conditioning device 18. In the conditioning device 18, ambient air U is dried from the waste heat Q3 by means of at least one adsorption refrigeration machine, by the refrigeration generated by the absorption refrigeration machine by means of the waste heat Q3 as operating energy being utilized to condense out water. The conditioned or dried ambient air UT is fed via a first air feed 54 to the cooling furnace 5 and is passed over the glass ribbon running through the cooling furnace 5 during the cooling process. Furthermore, the dried ambient air UT is also introduced

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into the cooling section 6 via a second air feed 55, where it is likewise passed over the glass ribbon which is passing through.

[0075] Then, a further heat quantity Q4 is branched off from the residual heat Q - Q1 - Q2 - Q3 at a further heat branch 26 of the waste gas discharge device 32, by means of which further heat quantity Q4 dried ambient air UT is once again generated in a conditioning device 19 from the ambient air U by condensation drying by means of at least one adsorption refrigeration machine, and this dried ambient air UT is fed via an air feed 56 to the glass store 8. In particular, air outlets are arranged in the region of the glass stacks to provide a targeted fanning of individual glass stacks with dried air UT.

[0076] Then, a fifth heat quantity Q5 is branched off from the residual heat Q - Q1 - Q2 - Q3 - Q4 which remains in a further heat branch 37 of the waste gas discharge device 32, and this fifth heat quantity Q5 is used in a further conditioning device 20 to dry ambient air U by condensing out water by means of a further absorption refrigeration machine. The dried ambient air UT of the further conditioning device 20 can then be fed via an air feed 57 to the coating device 9 and/or via a further air feed 58 to the glass finishing or glass processing 10 and/or via an air feed 59 to the laminated safety glass and/or insulation glass installation 11 in order to condition these further glass processing devices with dry process air.

[0077] The remaining waste heat Q' = Q - Q1 - Q2 - Q3 - Q4 - Q5 is then discharged to the outside in the waste gas A by the waste gas discharge device 32.

[0078] The heat branches generally comprise heat transfer circuits with heat transfer media, for example water or gas, and if appropriate pumps and/or heat exchangers, and form a waste heat transfer device for transferring the waste heats Q1 to Q5.

[0079] In the exemplary embodiment shown, the absorption refrigeration machines, for the purpose of drying the air, are each arranged in the vicinity of the process region that is to be conditioned, since the waste heat quantities Q1 to Q5 have to be transported over longer distances with a higher efficiency than the refrigeration of the absorption refrigeration machines and also the dried ambient air UT while maintaining the degree of moisture which has been set. However, it would of course also be possible for the refrigeration and/or the dried ambient air UT to be transported over longer distances through the process installation, given suitable insulation measures.

[0080] The absolute residual moisture in the dried ambient air UL in all the conditioning devices is preferably set at most to 6 grams (maximum 11 grams) of water per 1 kilogram of dry air, but at least in some cases may also be set differently.

[0081] On account of the conditioning, shown in the figure, of the glass throughout the entire production, from the batch in the batch feed device 2, through the melt in the glass melting device 3, the solidifying glass ribbon in the float bath 4 and the cooling glass ribbon in the cooling device 7, as well as the finished shaped glass bodies or panes in the glass store 8 and during further processing 9, 10 or 11, the moisture at its surface is always kept at a low level, so that the glass can only take up a small amount of moisture. As a result, corrosion to the glass caused by the action of water is considerably reduced compared to the processes known from the prior art.

[0082] In the embodiment shown in the figure, practically the entire process air conditioning of a flat glass process is shown. Of course, it is also possible for only part of these process air conditionings to be performed, in particular only in the cooling region of the cooling device 7, i.e. the cooling furnace 5 and/or the cooling section 6. Moreover, it is also possible for each process region 2, 3, 4, 5, 6, 8, 9, 10, 11 to be

assigned an associated refrigeration generation device and/or conditioning device for conditioning this process region with process air, or for individual refrigeration generation devices and/or conditioning devices to supply different combinations of process regions than those illustrated with conditioned air.

[0100] Any known embodiment, in particular in accordance with the prior art mentioned in the introduction, and in principle also any future embodiment, can be used for the production process itself, in particular its process stages or process regions 2, 3, 4, 5, 6, 8, 9, 10 and 11. The conditioning according to the invention can be used and is compatible with any known float glass process, but also with other glass making processes and also with steel making processes or the like.

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List of Reference Signs

2	Batch feed device
3	Glass melting device
4	Float bath
5	Cooling furnace
6	Cooling section
7	Cooling device
8	Glass store
9	Coating installation
10	Glass processing
11	Laminated safety glass installation
13	Batch preheating device
14	Combustion air preheating device
15	Refrigeration generation device
16	Condensation drying device
17	Condensation drying device
18	Conditioning device
19	Conditioning device
20	Conditioning device
26	Heat branch
30	Melting region
31	Region for melting until seed free
32	Waste gas discharge device
33	Heat branch
34	Heat branch
35	Heat branch
36	Heat branch
40	Refrigeration line
41	Refrigeration line
50	Air feed
51	Air feed
52	Air feed
53	Air feed
54	Air feed
55	Air feed
56	Air feed
57	Air feed
58	Air feed
59	Air feed
A	Waste gas
U	Ambient air
UT	Conditioned ambient air
Q, Q'	Heat quantity
Q1 to Q5	Heat quantity

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